Control on Green Energy Source and Ecologic Environment

Jie Wu[1], Si-zhe Chen[2] and Jun-hua Yang[3]

Abstract –The development and utilization of control strategies are closely linked with progress and requirement of society. All sorts of renewable green energy sources and ecologic environment construction become more and more paid attention to, as fossil energy resources become shortage day by day as well as environmental pollutions. This paper researches and analyzes energy sources status and sustainable development problem. Some key control projects and strategies were raised through studying wind energy conversion system and solar PV system. As an example, a hybrid generation station was constructed for environmental protection, energy conservation and harmonious ecologic environment. CAN bus technology was applied to monitor and control the wind-solar PV hybrid electric station and greenhouse as well as energy management.

Keywords - Green energy source, ecologic environment, hybrid electric station

I. Energy sources status and sustainable development

Energy source is the basic element of human existence and is also the main material foundation for the development of the national economy. Energy security is fundamental to the economic security of our country.

With international industrialization, global energy consumption is expected to be a 3% growth rate in future. The depletion of conventional energy resources is the dilemma we are facing. On the mid-1970's, global energy resources faced crisis and oil prices dramatic rise. It stimulated those big countries with great energy consumption to put the research and development of alternative energy sources on an important position. A new round of global energy crisis is a profound impact on the economic, political and military relations among all countries. It is an example that USA army attacked Iraq, the major oil producing country in the Middle East, in 2003.

The rapid development of economy and the low efficiency of energy utilization made the energy status of China more severe. The growth rate of GDP was 9.1% in 2003, but 30% of energy and raw material of the world were consumed and our GDP is just 4 % of the global production. The ecological environment will not endure if we only seek for the economic growth speed.

From the view of energy development strategy, human must seek the road to sustainable development of energy. With economic development and the improvement of living standard, there has been increasing emphasis on the improvements in the living conditions of human, and their awareness of environmental protection. Human urgently need some new energy sources which are clean, non-polluting and renewable. Developing and using renewable energy becomes a strategic choice. In fact, compared to coal, oil and other fossil fuel energy, some other energy such as water power, solar energy and wind power have much larger energy reserves. Theoretically, the solar energy that the entire earth absorbs in ten days exactly equals to all the world's energy reserves of fossil fuels[1]. The maximum utilization of the Earth's wind power is estimated to 1.3×1011kW. It is obviously much larger than the water power with 2.9×109kW. Statistics show that the useable wind energy can be four times larger than the total energy consumption in 1998[2]. Meteorologists estimated that about 1% of the solar energy received by earth was converted to wind energy. According to relevant statistics of the 1980s, only 1% of wind energy (0.01% of solar energy) was able to meet the energy need of the globe[1,3]. It can be predicted that the energy structure of the 21st century will undergo fundamental change. The traditional energy with fossil fuels as the main energy will be replaced by solar energy, wind energy, biomass energy, nuclear fusion and other new energy. Currently, about 85% of 12 trillion watts of energy consumption come from fossil fuels. To slow global warming, in the middle of this century, global primary energy will reach the aim without carbon dioxide emission. And then alternative energy outputs are three times of the current global energy consumption. Recently, many countries are setting down their energy plan. The European Union has announced that regenerative energy utilization will account for 50% of the whole electrical power production until 2050.

After 1992, the Chinese government presented environment and development strategy, asking for developing and spreading clean energy such as solar energy, wind energy, geothermal energy, tidal energy, biomass and other clean energy according to local conditions. Chinese government formulated the wind power, solar energy development projects and programs, named ‘wind project’ and ‘bright project’ [4]. However, the development of renewable energy in China is very slow because of the insufficient fund investment. The production capacity of solar photovoltaic technology was just 4.5MW and the equipment capacity of wind power only was 567MW in China at the end of 2003[5,6]. It is far behind developed countries. For instance, wind energy conversion equipment capacity was 14609MW in Germany. Therefore, the Commission of National Development and Reform proposed that by 2020, wind power capacity should reach to 30000MW, about 2% of the total installed capacity of power generation.

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This century will be an era that renewable energy and new energy replace conventional energy to play the leading role. The International Energy Agency forecasts that the proportion of new and renewable sources of energy will be developed to constitute more than 50% of the world's energy by 2060. Last four years, the global wind power generation has grown at an average annual rate of 65%, and the growth of solar energy is more than 30%, which even exceeded the development of the information technology industries.

II. WIND ENERGY CONVERSION SYSTEM AND CONTROL METHOD

In the numerous renewable energy and new energy technology development, wind power generation is the most mature, most large scale commercial development conditions and development prospects, the most competitive, the greatest potential. However, because of the intermittent and randomness of wind power, the quality of power was impacted greatly by the changes of wind speed and wind direction. The difficulty of the development of wind energy causes a number of particular problems to wind power technology and management systems, and makes wind power become a uncontrollable source. In fact, the power of wind energy conversion systems, if without control, does not have much commercial value. If it was directly put into the electric network, it will become pollution. In most cases, it can only contribute in harmonic, and it will affect the stability of the local power grid operation. In recent years, because of the rapid development and extensive application of technical control, power electronic technology and new materials technology, it creates favorable conditions for the use of wind power. In order to make wind power a high efficient, high quality and controllable energy, there are many control projects and control program of wind power, such as variable-pitch control (capturing maximum wind energy), variable-speed constant-frequency control, yaw control, brake control and so on. However, two core issues needed to be solved are: the biggest wind energy capture to improve wind energy conversion efficiency, and the improvement of power quality problems. Control methods from the most simple PID to more complex modern control methods, such as intelligent control, optimal control, adaptive control, variable structure control, robust control, differential geometry and so on[2,8]. Figure 1 is based on the CAN bus control system block diagram of the wind farm.

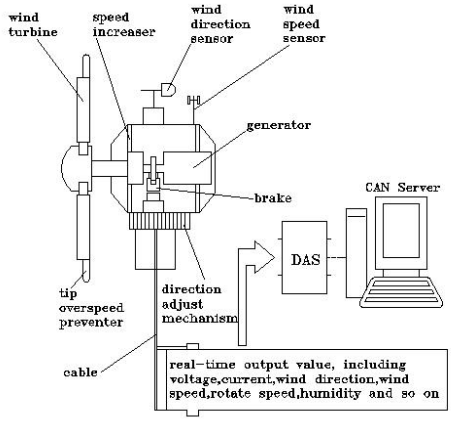

Fig.1: Monitoring and control of wind turbine

Based on the usual assumption of infinite power grid, in order to avoid storage problems and take into account the stability, reliability, the cost of power generation and other factors, currently, squirrel cage asynchronous generator is widely used in WECS with many sensors for three-phase voltage, current, wind speed ,wind direction, rotation speed, vibration, temperature and so on. AC excitation variable-speed constant-frequency double-fed generator is gradually adopted by the advanced wind turbine, with more than 60 sensors, for example the 1.5MW double-fed generator produced by GE.

A. Control of maximum power point tracking

According to the Betz theory of aerodynamics' the output power of wind wheel is

$$P_m = \frac{1}{2}\pi\rho C_p R^2 V^3 \quad (1)$$

where, ρ is air density (kg/m3), R is radius of wind wheel (m), V is wind speed (m/s) and C_p is wind energy power available coefficient.

We can know from this formula that: 1. If the wind speed is a constant, then P_m is in proportion to R^2 (R is the radius of wind-wheel,) that is to say, for getting higher output power, the wind-wheel need the largest radius as possible, or say the largest area the wheel blade can get. But big size wind-wheel will make the increase of the cost and the difficulty of install of the wheel. 2. If the radius of wind-wheel R is a constant, P is in direct proportion to V^3, so the wind generators should be installed in the areas with high wind speed, which relates to the environment. In the same position, the higher altitude, the higher wind speed will be, hence the tower-shelf should have a comparative altitude. 3. The wheel power is independent of the numbers of wheel lamina, but is in direct proportion to the air density. 4. The biggish wind energy power available coefficient C_p, can improve the wheel power.

The available wind energy power coefficient C_p is not constant, its maximum is 0.593 theoretically. This value is also be defined by Betz-limit, it changes with the wind speed, the generator's revolution and the blade parameters(the pitch angle for example), in generally, $C_p = C_p\ (\lambda = \frac{\omega R}{v}\ \beta, \lambda)$, λ is defined as $\lambda = \frac{\omega R}{v}$ here. In the formula, ω is the Wind rotation angular velocity.

Figure 2 plots the relation curve between the wind energy utilization factor and λ . Usually, the wind energy utilization factor C_p=0.2~0.5 in the horizontal axis, and in the vertical axis C_p=0.3~0.4.

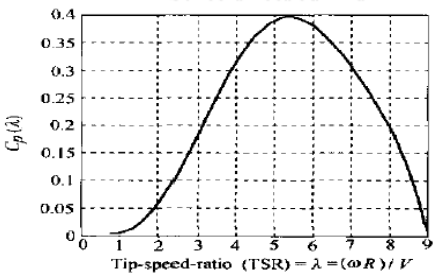

Fig. 2: Power coefficient

The overall design and operation strategy of the wind generator should ensure he safe of operation, in the meanwhile, to make C_p keep within the maximum during the operation area, to maximize the output power. We can know from formula (1) that, the output power of the wind generators is a cube function of the wind speed, that is to say, the bigger the wind speed, the higher the output power, but there are two limitations in the actual system: firstly, the maximum limitation of the electrical installations and electrical components, secondly, there is a rotate speed limit of the turbine components, especially the wind wheel. Thus, there are three typical run states: low wind speed phase operates in shift state, to maintain C_p be a constant value (to the extent possible, the best is to achieve the Betz limit), we can control the rotate speed of the generator according to the changes of the wind speed, to make λ unchanged until the rotate speed get to the limit. When rotate speed get to the limit, the wind speed increased further, control the operation at constant rotate speed until get to the maximum output power. At this point, C_p is not necessarily the maximum. When excess the rating speed, the output power gets to the limitation regulates the generators in constant output power. Figure 3 plots these three typical operating conditions. Figure 4 plots the control curve of maximum wind energy capturing.

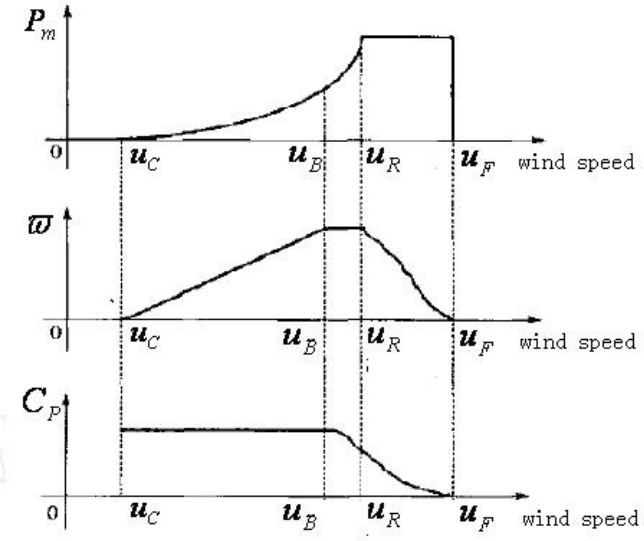

Fig.3: The three operation models of wind turbine

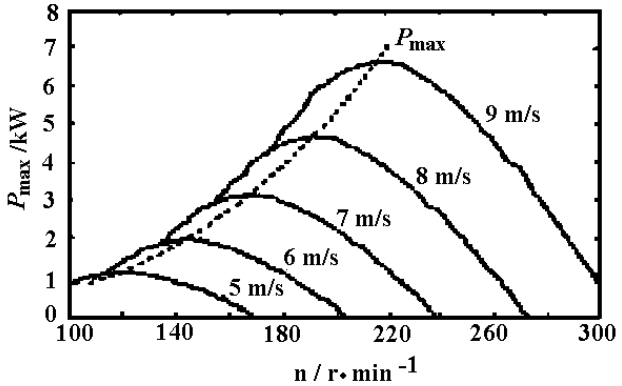

Fig 4: Power versus speed characteristics

B. Control of variable speed constant frequency generation

As we all know, the random wind, gust, and the uncertainty caused the frequency and voltage of the electric power from the wind power unit, this electric energy is lack of use except for the electric installations which have low-rise need for electric energy like heaters, we need to control and set the quality of the electric energy, the methods in common used are: constant speed constant frequency, variable speed constant frequency, variable frequency control. The VSCF control method can not only control the quality of the electric energy, and also can capture the wind energy furthest, the active and reactive power can be independently adjusted by decoupling control, and restrain harmonic, reduce the cost. The VSCF control projects we often use are: Asynchronous generator system, the exchange-fed generator excitation system, BDFM generator system, permanent magnet generator system. Because the electronic equipment of the double-fed electrical generator play the pole only in the control loop, equipment capacity generally should not exceed 30% of the power output of wind energy conversion system. The cost of equipment can be significantly reduced. Thus BDFM is a kind of wind energy conversion methods which have good prospect. BDFM, got rid of the slide loop and brush which can be easily attrited, improved the reliability of wind energy conversion system.

VSCF control can convert wind energy to alternating current which has constant frequency and constant voltage power. The wind turbine generator can be freely integrated into electric network.

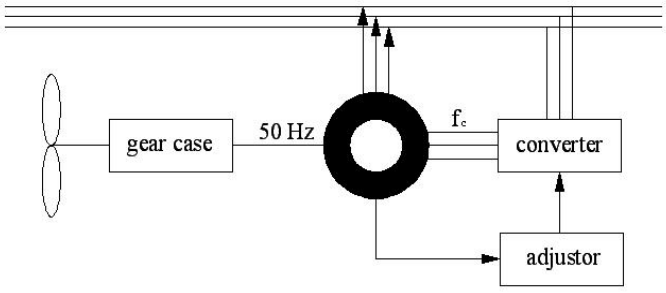

Fig.5: Doubly-fed generator

The increasing depletion of fossil fuels, made the world's growing emphasis on the development and utilization of renewable energy. Various wind turbines emerge. Two major trends in the development of wind power generation systems: on the one hand, the development of greater capacity single large wind turbine generators, other developing distributed small and micro wind power generation system. Large-scale wind power equipment can reduce the cost of wind power generation, distributed small wind power generation system, which is designed to solve distributed remote areas scattered local power supply, can save the planning and construction of the supply networks which are hardly cost-effective.

III. CONTROL OF SOLAR PV STATION

A. Solar PV generations

The solar photovoltaic power generation is an important way for use of solar energy, and our country is focus on developing this green energy. Practically in China's western region, with a scattered population, and economic backwardness, many households without power and the use of solar energy has unique conditions. Along with the implementation of the western development policy and the "bright project", the implementation of solar photovoltaic technology has been rapidly developed. China's strong demand for photovoltaic products, PV batteries increased by 30% in average on sales. Until 2000, the retain of PV products got to 15MW, which are mainly used in telecommunications, railways, television, meteorology and navigation. cathodic protection, etc. Housing-use PV systems and independent photovoltaic power plant operators have made great progress. According to the solar energy resources developing plan made by the Development and Reform Commission, Ministry of Science and Technology, the development plan "Bright Project" plans to reach a total installed capacity of 300 MW photovoltaic power system in 2005, World Bank GEF project started in 2001, plans for the installation of 10 MW of photovoltaic power systems in rural areas in five years.

Solar energy generates electricity, including solar photovoltaic generators and large thermal electrical plants. Photovoltaic power generation has a conversion efficiency of about 10%~20%. It includes crystalline model and non-crystalline model. Crystalline model can be divided into single-crystal model and multi-crystalline model. About solar energy thermal electrical plants, trough solar power's conversion efficiency can get to 15%, Spain will build the largest trough thermal electrical plants of Europe. Furthermore, there also have other forms, as for Tower power etc.

B. Control of solar PV station

(1) Sun tracking control, realize the maximum capture of solar energy' power input.
(2) Maximum power output control of solar energy' battery array (MPPT), we often uses the optimization algorithm.
(3) Solar inverter parallel and parallel control.
(4) Wind-solar PV system

This wind, solar control is the basic bottom module control, to constitute an optimal operation of wind-solar hybrid power systems. An upper energy management system is needed, and equipped with batteries. Figure 6 is a typical hybrid power system maps.

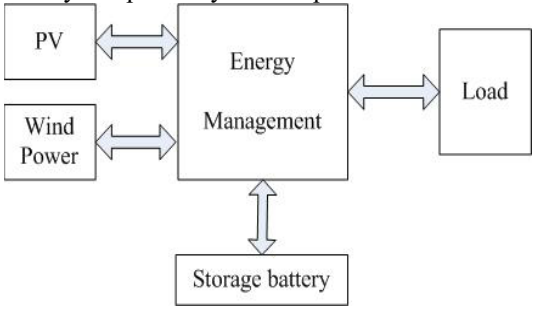

Fig. 6 Hybrid electric station

IV. CONTROL ON ECOLOGIC ENVIRONMENT

Research result indicates that 34% of the environment pollution is relate to construction industry, and 50% of the energy is used in the constructing and using of construction. Researching continuable ecotypic industry, including ecotypic house and greenhouse, is one of life aims of human being.

A. Control on ecologic environment

Using ecological principles, ecological balance and sustainable development and integrated follow optimal efficiency, controlled substances in the construction of energy conversion cycle of the system in an orderly manner, properly regulated to a small residential ecosystem, to get a highly efficient, low-consumption, low waste, alternative residential intelligent ecological environment, as illustrated in figure 7.

Specific measures:

1) Control of water recycling, rainwater collection system.
2) Develop the renewable energy: solar energy integration with the unified structures (building integration: BIPV), wind energy, natural temperature.
3) Use new power-saving, environmentally materials and indoor air quality monitoring.
4) Take full advantage of the characteristics of the climate and environment, farthest use the natural daylight and ventilation to reduce energy consumption.
5) Green and Waste disposal.

Fig. 7 A typical ecologic residence

B. Computer control system of greenhouse

Complete environmental control system of greenhouse including sensors, controllers and implementing agencies, generally using distributed computer control. The main functions of the control system are:

Throughout the vegetal process of crops, record the condition of indoor ecological environment and control, to provide a basis for optimization Model of ecological environment.

1. According to the optimization model of ecological environment, make optimal control strategy.

2. According to the optimal control strategy , control heating, irrigation or ventilation.

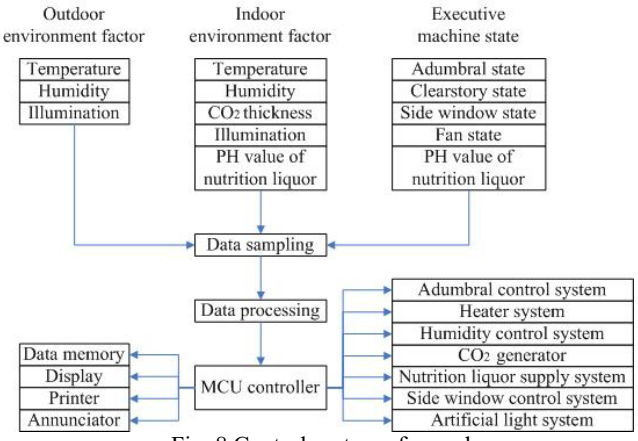

Fig. 8 Control system of greenhouse

C. Modelling and control of greenhouse

Greenhouse is one of the important signs of modern agriculture, modeling and control of the greenhouse environment began in the 1960s. The expression of greenhouse model is:

$$\dot{T}_g = f(T_a, T_p, q_s, T_g) + g(T_a, u, Q, eg, T_g) \quad (2)$$

where, f is the part of certain parameters; g is the nonlinear part of time-varying parameters; T_g is the greenhouse air temperature; T_p is the heater temperature; q_S is the solar thermal radiation energy; T_a is the outdoor temperature; Q is the solar illumination angle; u is the outside wind.

C.1. Modelling methods of greenhouse

1. Based on the thermal energy balance modeling, mechanism analysis and system identification will be integrated to model.
2. Based on the expert system modeling and absorb the experience of agricultural experts.
3. Based on the fuzzy neural network modeling, genetic algorithm was used to train the network parameters.

C.2. Adaptive control system of greenhouse

Because of the outside environment factors such as radiation, or outdoor temperature, humidity, wind speed and so on. The greenhouse environment model parameters change. Conventional computer control cannot guarantee the control quality, more advanced control strategies are needed, such as the adaptive control. Fig. 9 is a typical adaptive control heating system of greenhouse.

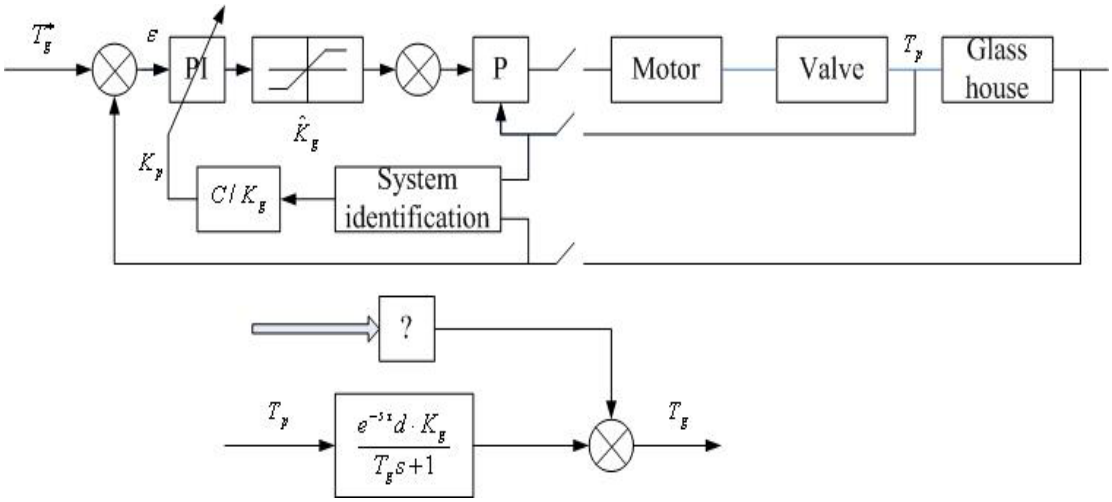

Fig. 9 Adaptive control system of greenhouse heating

D Control system of hybrid electric station and ecologic environment based on CAN bus

The technology of CAN bus is the amalgamation and integration of computer technology, network and communication technology and control technology. Using CAN bus for wind-solar energy hybrid electric station, greenhouse to monitor and energy manage, can make a environmentally, power-saving and harmonious ecological environment. As an example, the research center of renewable energy source of SCUT lays a 10kW solar battery array, there sets of dynamo (of a 1 kW horizontal axis, a 2kW vertical axis and a 2 kW horizontal axis) and the storage battery array on the roof, which together form a 15kW hybrid electric system. It also builds a 60m^2 greenhouse. The whole system use CAN bus technology, look at the Fig.10.

Fig. 10 Research center of renewable energy source of SCUT

V. CONCLUSION

As conventional energy being exhausted, it is urgent to research, develop and utilize the green regenerative energy sources, which is represented by the wind energy and the solar energy. For example, in European Union with 15 member countries, its total target in 2010 is to make the utilization of green energy reach 22% among the total power production.

Based on the ecological theory, and following the principles of ecological balance, the sustainable development and the optimization of the system efficiency, the objective of the control is to make the substance energy sources be transformed orderly and circularly in the building system, also to construct the house to be a small ecological system, thus we can get an intellectualized and ecological resident environment with high efficiency, low-consumption, low-scrap and light pollution. This is just the requirement of the present time.

The new research subjects are coming forth endlessly with the development of green energy source and ecological environmental control.

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BIOGRAPHY

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